Hon: Edward Everett
with deep respect
B. A.

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AN ACCOUNT OF

THE OBSERVATORY

AT PULKOWA,

AS WRITTEN FOR THE NORTH AMERICAN REVIEW; JULY, 1849.

THE OBSERVATORY AT PULKOWA.

Description de l' Observatoire Astronomique Central de Poulkova. Par F. G. W. Struve, Membre de l'Académie Impériale des Sciences de St.-Pétersbourg, Premier Astronome et Directeur de l'Observatoire Centrale. St.-Petersbourg, 1845.

Who has not heard of Pulkowa, — Eldorado of astronomers, as the enthusiastic Biot calls it? In comparison with its great observatory, for vastness of plan and magnificence, for beauty of detail and exquisite organization, the historic Uraniburg and Cassel become insignificant. Yet a little while ago, we looked back with wonder to the times when Tycho, Longomontanus, Roemer and Horrebow controlled resources and enjoyed facilities, the mere narration of which would have seemed to us like fable, did not the monuments of those times still exist.

Who has not heard of Pulkowa? And yet when in March, 1834, one of Struve's assistants placed a transit instrument on the summit of the hill, upon the spot where the great central tower now stands, Pulkowa was a small village of serfs,— celebrated for nothing under the sun, except perhaps that, being an imperial domain, its log-houses were a little better, and its inhabitants a little happier, than those of most other Russian villages. It was not until August, 1839, that the observatory was inaugurated, and not until the middle of the year 1843 that it was completed.

It is difficult for us to refrain from alluding, in terms of heartfelt gratitude, to the kind welcome and princely hospitality we enjoyed at Pulkowa. The wish to diffuse a more

accurate knowledge of this observatory, whose geographical position alone would prevent most of our astronomers from visiting it, has prompted us to give a short account of its history, progress and condition.

Two illustrious directors of European observatories, Messrs. Schumacher and Airy, have already visited Russia for the purpose of making themselves acquainted with the Central Observatory. The Astronomer Royal of England left Greenwich, full of predilections for English instruments and English methods of observation; he disliked the Munich refractors, would have nothing to do with counterpoises, and thought the Prime Vertical Instrument inaccurate and clumsy. On returning home, he wrote to Professor Schumacher the memorable words: — "I trust, therefore, that you will not regard as unfounded the opinion which I express, that no astronomer can feel himself perfectly acquainted with modern observing astronomy in its most highly cultivated form, — whether as regards the personal establishment, the preparation of the buildings, the selection and construction of the instruments, or the delicacy of using them, — who has not well studied the Observatory of Pulkowa."

The Central Observatory being completed, and the corps of observers actively at work, there remained still one thing undone. An accurate description of the observatory and of its instruments was needed, that the improvements here introduced might not remain unknown to other astronomers. In the magnificent work before us Struve has done this, and the "Description de l'Observatoire Central" is the only textbook from which the student can now derive an accurate knowledge of the refinements of modern astronomical instruments, and of observations of the modern school. The work is in two beautiful volumes, the one consisting of a description of the establishment itself and of its instruments to their smallest details, and the other containing the drawings necessary to illustrate the text.

The instruments are all constructed upon the German system, and the whole observatory forms a monument to the excellence of that system. No ungainly quadrants, or mural circles for determining declinations alone, are to be found there; — no broad wheels with graduation on their rims, to be read off by microscopes placed around like spokes, whose various readings can only be brought into apparent harmony by the application of some empirical "correction for runs;" — no instrument in which the accuracy of the observer is

entirely dependent upon the degree of skill exercised by the mechanician; nor yet zero points, which describe little diurnal and annual orbits, or subject to all the thermometric and hygrometric motions of stone pillars.

Before considering farther the merits of the observatory, we will give a short account of its origin and history, which are discussed at length in the "Description."

It is worthy of remark, that the little realm of Denmark has not only done more for astronomy, in proportion to its size and finances, than any other country in the world, — an enviable distinction which even now, in its days of political tribulation, does not desert it, while it enables such illustrious sons as Schumacher and Hansen to labor for present and future ages, — but it enjoys the honor of having established the first public observatory in Europe. The first permanent European observatory was that of Copenhagen. In less than thirty years after, that of Paris was founded. That of Greenwich followed after a short time; and soon, under the direction of Cassini and Flamsteed, both were rendering eminent service to astronomical science.

It was under Peter the Great that Russia made the first steps toward taking the scientific position which she now holds. This enlightened monarch founded, in 1724, the Petersburg Academy of Sciences, and placed under its superintendence an observatory, the building of which was completed in the following year. No pains was spared to provide proper instruments, and Lalande speaks of it as one of the most magnificent observatories in Europe. A conflagration in the year 1747 destroyed the whole building of the Academy, and the observatory, with all the instruments which it contained, fell a prey to the flames. The munificence of the Empress Catharine restored it, and provided it anew with the most valuable instruments to be had at the time, among which were a five-feet transit instrument and a huge mural quadrant, by Bird, which to this day remains fastened to the wall of the building.

Still under the direction of the Academy, the new observatory rendered important services to science, and boasts, among other great names, those of Delisle, Lexell and Schubert. Observatories have since sprung up in all parts of the Russian empire, at Nicolajew, Åbo, Dorpat, — a name rendered illustrious by the labors of the same great astronomer who now adorns the Central Observatory, — Kasan, Moscow, Helsingfors and Kiew. And without going back to the times

when Bernoulli, Euler or Lagrange sat in the Imperial Academy of Sciences, we must assent to the remark of Struve, when he says, that within a single generation more has been done by the government in Russia, for the advancement of astronomy, than in any other country; more, indeed, than was ever done within the same period, if we search through the whole history of astronomy.

And now the magnificent Central Observatory has been called into being, — its birth marking a new era in practical astronomy. The Academy had seen for some time that the observatory of St.-Petersburg had fallen behind the age. It was no longer able to answer the demands which astronomy in the nineteenth century was justified in making. The instruments, once unequalled, were now old-fashioned, and much inferior to the new instruments of the Germans. Their position, on a high tower, was far from being firm enough. There was need, too, of more room, as is sufficiently attested by the fact, that a magnificent twenty-feet telescope, by W. Herschel, lay, as it still lies, unpacked, for want of a proper place in which to mount it.

The present emperor, Nicholas, determined therefore to build an observatory, and to spare nothing which should tend towards making it as complete and serviceable as the present state of astronomical science would allow. For this purpose, he requested the Academy to appoint a commission to superintend the plans and arrangements. Struve, at that time director of the Dorpat observatory, and whose biography might almost be said to be the history of stellar astronomy during the same period, was placed in this commission.

The first step was to settle definitively the constitution of the new observatory. The field of astronomy is so vast, that no one establishment can cover it all, and it is of the highest importance, that for every observatory a definite line of research should be laid down. As Mr. Airy, the Astronomer Royal of England, and many distinguished men before him, have strenuously insisted, it is earnestly to be desired that the energies of every observatory should be devoted to some particular department of astronomy. This not only prevents the astronomers from wasting their time in fanciful speculations, or in flitting from one investigation to another, but is imperatively necessary for giving the observatory a proper place in public estimation. The objects to which the commission decided that the energies of the new institution should be devoted, were,

1st. Regular observations, as complete as possible, whose end should be the advancement of astronomy as a science;

2d. Corresponding observations for the geographical expeditions in the Russian empire;

3d. The advancement and development of practical astronomy in its geographical and nautical applications.

It was with reference to this threefold purpose that the plans for the instruments and for the buildings were adopted. The regular observation of the sun, moon, and large planets, has been for a hundred years the special province of the observatory at Greenwich, and the whole powers of so distinguished men as those who have presided over that establishment, have been devoted to perfecting that particular class of observations. It was, therefore, thought advisable to leave this department to Greenwich altogether, while there are so many others where accurate observations are still more needed.

The hill of Pulkowa, twelve miles, (seventeen *wersts*) south of the Admiralty palace in St.-Petersburg, and belonging to the imperial domain of Tsarskoïe Seló, was selected as the most favorable site for the observatory. The high road from the capital towards Warsaw runs almost due south, forming a straight line for the whole distance, until it reaches the base of the hill, round which it winds. This hill is neither very steep nor very high, but is a prominent feature in an almost level plain, like that on which the Russian capital is situated. It is about two hundred feet high; and just in the prolongation of the straight line formed by the road, now rises the central tower of the observatory. When, therefore, the traveler, who leaves St.-Petersburg, by the barrier of the triumphal arch, looks before him, the magnificent façade and cupolas of the observatory appear precisely in front, as though the great *chaussée* were but an avenue leading to Pulkowa.

The roads to Warsaw and to Moscow separate about half a mile before reaching the observatory, — the Warsaw branch continuing, as we have said, until it reaches the base of the hill, and then winding round it on the eastern side. This circumstance effectually secures the instruments from dust and tremors; while the height of the observatory commands a wide, clear horizon, and a more healthful air than those enjoy who live two hundred feet lower, on the plain. A remarkable testimony to the healthfulness of the situation is furnished by the fact, that, while that dread scourge of Russia, the

cholera, was this last summer sweeping away its hundreds of thousands,— while more than eighteen hundred fell a daily sacrifice to the pestilence, — while the Russian realm, according to one of the St.-Petersburg physicians, was decimated, and scarce a man or woman could be seen, who was not in mourning, — the inmates of the observatory were wholly unscathed by the fearful disease. The writer of these pages was at that time in Pulkowa, and felt there as secure as in his native city.

The tract of land given by the emperor, contains five hundred and forty-five acres, (twenty *dessjatines*,) being two thousand two hundred and five feet long, and one thousand five hundred and eighty-two wide at its greatest breadth. No houses can be built in its vicinity to dim the air with smoke and heated currents; for by a special edict of the emperor, it was ordained that no dwelling-house should ever be erected within a *werst*, (or two thirds of an English mile,) of the southern frontier of the land belonging to the observatory. The future astronomers of Pulkowa are thus to be exempt from what has been so fruitful a source of annoyance to the observatories of Berlin, Paris, and even Greenwich, and what bids fair, at some not very distant day, to be a serious impediment to the labors of our own observatory at Cambridge.

Struve's reputation at the head of observing astronomers had already been earned at Dorpat. Under his superintendence, and according to his plans, the great refractor at that place had been built, erected, and used. His application of clockwork to telescopes, his "Mensuræ Micrometricæ Stellarum Duplicium," his determination of the parallaxes of α Lyræ and Polaris, and above all the almost incredible accuracy to which he had brought his observations, had united to give him this position. The investigation by Bessel of the parallax of 61 Cygni, was undertaken subsequently to Struve's similar determination of that of α Lyræ, although published a short time before, and was, indeed, undertaken at Struve's suggestion. Struve was appointed director of the new observatory, and leaving Dorpat, applied himself with great zeal to the labors thus imposed upon him. He made two journeys to the *Ausland*, — a somewhat greater undertaking in Russia than it is in America, — and visited the artists whom he had selected as the most competent to construct the instruments.

The accuracy of which the modern system of astronomical

observation is now capable, is considered by many as the highest which the nature of our senses will permit. Without altogether assenting to this proposition, we must, nevertheless, acknowledge that the precision already attained approaches this limit, perhaps as nearly as we can expect for generations to come. The harmony which can now be brought about between observation and computation is quite astonishing. But to answer all the conditions requisite for the highest degree of accuracy, instruments and modes of observation are needed, entirely different from those used before the refinements of Gauss, Bessel, and Struve. The sources of great errors are few, and may be avoided in almost all instruments of the present day; but minute errors can only be avoided in instruments constructed with the special aim of allowing observations to be made under as many different circumstances as possible, that, by combining the results, the errors may be eliminated. The only means of attaining what is now called accuracy is,—not, as was until lately the usage in all countries, and is still in some, to adjust the instruments with all possible care, and then to rely upon their indications, — but to consider the best adjustments as only such approximations to accuracy, that in calculating the corrections, the terms depending upon the squares or higher powers of the errors may be neglected as inappreciable. Observations are then made under circumstances designedly varied in such a way, that in the proper combination of results, the errors may be not only eliminated, but precisely determined; for a result, whose exact deviation from the truth is known, is as good as one affected by no errors whatever.

Some of the sources of error lie in the instruments themselves, and can be determined once for all,—the investigation being repeated, however, from time to time, at such intervals as may ensure that any change in the instrument shall be promptly detected. The discharge of a cannon in the neighborhood, a severe clap of thunder, the slamming of an observatory door, or a strong draught of wind, might easily change the collimation of a transit instrument or meridian circle; and, after any such occurrence, a new determination ought to be made. The values of the divisions in the best levels and micrometer scales are quite different at different temperatures, and most scales change slowly as to their values for the same temperature in different years.

Other causes of inaccuracy, which vary from hour to hour, must be investigated for every observation, where the high-

est precision is required. Such are the changes in the inclination and azimuth of the axis of a meridian or prime vertical instrument, or the variation of the zero point on a declination or altitude circle. Still another class of errors arises from the want of strict mathematical accuracy in all works of human art, in cases where the precise determination of the error is impossible. No screw or micrometer circle was ever made in which the dead motion did not furnish an element of error, and many astronomers, who have never investigated it, would be astounded at the amount of error thus introduced into their observations. The want of strict parallelism in the spider-lines of a diaphragm, and the breadth of the lines of graduation on all scales, belong also to this category. Errors arising from such sources as these cannot always be avoided, but may always be materially diminished by the skill and ingenuity of a cultivated observer.

The first requisite, then, of an astronomical instrument at present is, that it be constructed not only with the greatest possible accuracy, but also on such a plan as to allow us to determine the precise magnitude of the errors which must necessarily exist. It is in this that the German instruments constructed by Reichenbach and Repsold, with the aid of plans suggested by the genius and experience of Bessel, Gauss and Schumacher, so far surpass all others, and this is the idea which the combined talent of all the German astronomers has since been constantly laboring to develop. Hansen and Encke, Ertel and the younger Repsolds, have carried on the work, and Germany still leads the way.

It is indeed almost as much to the talent and skill of the Fraunhofers, Reichenbachs, Repsolds and Ertels, as to the labors of those who use their instruments, that we owe the accuracy of modern physical and astronomical measurements. The precision of these instruments is such, that the very making of them has become Art, — Art in the high sense of the word. A mechanician of the rank to which these men belong, is a genuine artist; — he creates as well as executes. No one but the mathematician or the physicist can appreciate the labor, skill and ingenuity necessary for grinding what is commonly called a plane surface so that it shall be truly, mathematically, a plane, from which all parallel rays of light shall be reflected parallel; — for making a material circle which shall be strictly a circle, with circular curvature in its smallest, microscopic parts; — or for constructing an astronomical clock which shall, in winter or summer, through all

changes of temperature, retain the same rate. All these things have been done. The men of whom we speak have, as Encke has brought home to the conviction of astronomers, devoted their property, their powers, their health, their lives, to satisfy the constantly increasing requisitions made upon their profession by the progress of science; and their toil, zeal, and genius, demand our gratitude. Without them Struve could never have laid down his brilliant theorem, '*Alles Sichtbare ist messbar ;*' — Whatever can be seen, may be measured.

The construction of all the instruments for Pulkowa, excepting one or two of the clocks and chronometers, was confided therefore to German artists. With them Struve discussed at length each change that he proposed to introduce, and went through all the details, from the largest counterpoise to the smallest screw. The plans for all the instruments were then subjected to the judgment of the first continental scientists,— Bessel, Encke, Humboldt, Lindenau, Olbers, Schumacher, and Steinheil. Thus, although all the instruments were constructed in accordance with the general system which has prevailed in Germany since the time of Reichenbach and Fraunhofer, there was not one which was not in some respects new; and we believe the artists who were selected to construct the Pulkowa instruments still look upon those instruments as their masterpieces. The great refractor by Merz was of a size till then deemed impracticable, and we may well be proud of possessing in our own country its exact duplicate.

The construction of the famous Dorpat refractor formed an era in the history of astronomical instruments. Struve published, in 1825, a detailed account of it, and descriptions and drawings of it are to be found in the Cyclopedias. It was Fraunhofer's masterpiece, both as regards the construction and the glass. The extreme difficulty of obtaining large pieces of glass suitable for astronomical and optical researches is well known. The obstacles in the way of their manufacture are almost numberless, and the object-glass of the Dorpat refractor was the largest achromatic lens known which was free from fault, being nine French inches in diameter. For a good object-glass, both the flint and the crown lenses must not only be free from striæ and air bubbles, but, what is far more difficult, must be perfectly homogeneous, having the same refracting and dispersing power in every part. If the glass be cooled too quickly, the parts at the edge, and near

the surface, acquire different optical properties from those near the centre. If cooled too slowly, the lower portion becomes, in consequence of the weight of the mass above it, much denser than the surface. So when, after much pains and many vain trials, a glass has been cast free from all striæ, bubbles, and cloudiness, it is still, in nine cases out of ten, however beautiful in appearance, of small value for the optician or astronomer. Experience, too, has shown, that of two different castings, performed under the supervision of the same persons, and apparently under the same circumstances, the glass may be very different in its optical properties.

Fraunhofer claimed, however, to have discovered an important secret in the manufacture of the glass, which, upon his death-bed, he imparted to his successor, and which Merz, the present head of the establishment, purchased at a high price. No sooner had Fraunhofer, after a long series of costly experiments, succeeded in obtaining the two glasses which form the Dorpat lens, than it was secured by Struve for his observatory, and the refractor built upon a plan devised by himself and Fraunhofer jointly. This was the first instrument in which, by the application of clockwork, the telescope was made to follow the stars, keeping pace with their diurnal motion, and thus admitting of an accuracy and care in the micrometric comparisons, which would be impossible if the star were moving through the field of vision. The whole principle of the mounting was new and peculiar, the telescope being on one end of the axis and balanced by a counterpoise at the other extremity. Experience has shown the great practical advantage of this construction, which has been since invariably adopted for all large refractors, excepting in England.

Since the erection of the Dorpat instrument, Fraunhofer and his successors had made several other similar refractors, one of which, that of Bogenhausen, was of still larger dimensions, having 10.5 inches aperture. Emboldened by this success, they applied themselves, at Struve's instigation, anew to their work, and succeeded at last, in 1837, in producing two object-glasses of 14 French inches (14.95 English) in diameter. Struve selected one of these for Pulkowa, which was mounted much like the Dorpat telescope, but with some farther improvements, and which arrived at its destination in 1839. The other was mounted in the same way in 1845, and is now at the Cambridge observatory. A detailed description is therefore unnecessary, and the more so as the

great refractors at Cincinnati and Washington are mounted in the same way. The length of the instrument is twenty-three feet; the weight of the part which moves on the hour-axis is seven thousand pounds. The tube is conical, being at the one end seventeen inches, at the other eleven and eight tenths in diameter. Its construction is very curious. A great number of thin strips of pine wood, each being of the entire length of the tube, and slightly wedge-shaped, are glued together side by side, and in different layers, the whole mass being an inch thick, and veneered externally, so that a cross section of the tube would appear to be formed of a multitude of thin radiating slips of pine an inch long. This curious structure has been found to possess all the inflexibility of metal, while it is, of course, very light in comparison. The equilibrium is preserved, and ease of motion effected, by means of eight counterpoises. The friction of the hour-axis is diminished by one, that of the declination-axis by two, of these; two more serve to protect the tube from any tendency to flexure, while the three others act to produce equilibrium in the whole huge mass.

It was with the mounting of this instrument that Professor Airy "was not satisfied."

Merz also furnished a heliometer like Bessel's, but with an aperture of seven inches and a half. This instrument has not as yet been systematically used, and Professor Struve contemplates some important changes in the mounting, by which it will be made to resemble the magnificent instrument on which Repsold has been employed the last few years, and which is about to be mounted for Professor Johnson, at Oxford. The transit instruments were by Ertel; and the new vertical circle by Ertel, on Struve's plan, is already too well known to astronomers to need any description here. It is the instrument with which Peters has made his remarkable observations on the parallax of the fixed stars.

All the meridian instruments designed for solar observations are provided with diaphragms of thin brass plate, to protect the interior of the tube, and especially the plate which holds the spider lines, from the sun's rays. Care has been taken to place these diaphragms in such a way, that they can exert no pressure on the sides of the tube by their thermometric expansion. Of course, the instruments and piers here, as in every well ordered observatory, are protected from the rays of the sun during the observation.

The Prime Vertical Instrument, by Repsold, is perhaps the

greatest triumph of mechanical art in existence, as regards its exquisite accuracy. This instrument was designed and is used by Struve personally for the determination of the Aberration of the fixed stars, Nutation, and Annual Parallax. The telescope is at the extremity of an immense steel axis, and balanced by a counterpoise at the other end. The nature of the observations requires, that a star be observed on each side of the zenith with the instrument in the two different positions, — telescope north, and telescope south, — so that before an observation is completed, the whole gigantic mass, — axis, circles, tube, and weights, — must twice be lifted from the axis supports, technically called the Ys, and turned entirely round. This must be done, too, as rapidly as possible; for, as the astronomer knows by sad experience, the star will not wait for him. The slightest jar to the instrument, the smallest scratch upon the axis, which a particle of dust might yet produce, would be fatal to the accuracy which Struve requires in his observations. It seems incredible, but is true, that the huge mass, weighing a thousand pounds, can be lifted, reversed, and the axis deposited again in the Ys, in sixteen seconds. The force necessary to lift it for this purpose is, in summer, two pounds and two thirds. The writer reversed the instrument in sixteen seconds and a half, with his little finger alone, — raising the whole, turning it round, and carefully replacing the axis.

Concerning this instrument, the English Astronomer Royal makes the following curious remark: — "Before I had examined this instrument at Pulkowa, I was not disposed to recognize it as one competent to the delicate determinations for which Mr. Struve intended it. After a careful examination of it, I am bound to say, that my objections to it are in part removed, but not entirely. The firmness of the instrument exceeded my expectations; yet I am still unwilling to adopt for this use a form which no one would for a moment tolerate in a transit instrument. But in stating these objections to the instrument, I must state that they apply to it as an instrument to be used by astronomers in general, and not as one to be used by Mr. Struve. In his hands, I have no doubt that the accuracy of the instrument is limited only by the circumstance which he himself pointed out to me, — namely, the difference of radiation from the different piers; — in other hands, I should have no such confidence in its accuracy." Those who espouse the German system in instruments and methods of observing were by no means dis-

pleased with these words of its most accomplished and influential opponent.

The great meridian circle was also the work of Repsold, and is far superior in its proportions, its exquisite execution, and the improvements which have been introduced, to any which has as yet been made. Among the latter are especially to be mentioned the collimators, the arrangement, originally suggested by Hansen, and made in all the Pulkowa instruments, by which the eye-piece and object-glass are capable of changing places with one another, to eliminate any flexure of the tube, and the removal of the microscopes from a circle resting on the axis to a frame fixed to the stone pier, and provided with levels.

Astronomical clocks were furnished by various makers; but the honor of constructing the great normal clock, to which all the others are referred, was reserved for Kessels of Altona. This clock is fixed in the interior of one of the pillars of the central rotunda, where the variations of temperature are surprisingly small. The niche in the interior of the pillar is sixteen inches deep, twenty-three broad, and five feet eight inches high. It is lined with copper, to guard against dampness, and covered in front with a slab of glass, pierced with a hole through which the key is introduced when the clock is to be wound up, but which is of course kept closed at other times. The daily variations of temperature are less than a degree of Réaumur ($2\frac{1}{4}^\circ$ Fahrenheit); and so accurate is the clock, that, according to Professor Struve, the only source of change in its rate is the change of barometric pressure. The daily rate of the normal clock varies thirty-two hundredths of a second for every inch of barometric fluctuation. Kessels furnished two pendulums for this clock, the one being what is called a gridiron pendulum, the other mercurial. The latter alone is used, being considered, from its simplicity and for other reasons, much preferable to the more complicated gridiron pendulum in situations where the variation of the temperature is not great; although the other ought to be used when a clock is exposed to thermal changes.

Kessels also made three chronometers for Pulkowa; Tiede, Dent, and Hauth of St. Petersburg furnished the other clocks. One of Hauth's, in particular, between the transit instrument and the vertical circle, is most ingeniously contrived, having a dial plate and three hands on each side.

On entering the Pulkowa observatory by the chief door, the visitor finds himself in a magnificent rotunda, hung round with the portraits of different astronomers and of the artists who furnished the chief instruments. All of these are paintings in oil, and are either originals, or copies taken for Pulkowa from the best originals which exist. The portrait of Copernicus is an original, painted in Italy on copper, and the gift of the emperor. The copies are portraits of Tycho Brahe, Kepler, Hevel, Newton, Flamsteed, Halley, Bradley, Roemer, W. Herschel, and Schubert. The originals, besides Copernicus, are Airy, Bessel, Ertel, Gauss, Hansen, Hansteen, J. Herschel, Merz, the two Repsolds, Schumacher, South, and Steinheil. Most of them were painted by Jensen of Copenhagen, and are very striking likenesses. Those of Gauss and Schumacher are the originals of the lithographed portraits, of which some copies exist in this country. It is intended to procure portraits of the eminent French astronomers, which, it will be remarked, are as yet wanting in the collection.

At the side of the rotunda, opposite the great entrance, stands a fine marble bust of the emperor Nicholas, to whom astronomy owes a debt of gratitude. To the right and left, doors open into the meridian observing rooms; and opposite to the entrance, behind the bust of the emperor, is a door which leads to the library and to the Prime Vertical Instrument. Immediately to the right of the chief entrance is the flight of stairs, which conducts to the central tower, where the great refractor is placed, and which is directly over the rotunda.

Of the library we must content ourselves with saying, that no book of value on any department of astronomy is wanting which has been obtainable since the observatory was established, and that agents are scattered all over Europe, ready to avail themselves of the first opportunity of acquiring rare books as they may come to light from time to time. Even now, the elegantly classified catalogue of the Pulkowa library serves as an astronomical bibliography. Among the rarest works are the *Machina Cœlestis* of Hevel, all the copies of which were destroyed by a fire on the day before its intended publication, except a very few which Hevel had sent off in advance, as presents to his intimate friends. Of the *Epistola ad amicum de cometa anno* 1677 *Gedani observato*, only two other copies are known to exist.

An admirable nucleus for the collection was furnished by

the purchase of the library of Dr. Olbers, immediately after his death. This was one of the most valuable and complete private libraries in existence, and especially rich in works relating to cometography. For more than fifty years, this eminent astronomer had been constantly collecting works on his favorite subjects; and as he had fortunately never been fettered by the want of sufficient pecuniary means, he had succeeded in gathering about him the rarest and most valuable works relating in any way to comets, as well as those having reference to any unsettled points in the history of astronomy. This library was secured for Pulkowa through the agency of Professor Schumacher, who, standing as he does above all petty national jealousies, was never found wanting either in zeal or power to advance the interests of astronomical science. Would that the opportunity offered astronomers, three years ago, of acquiring the library of the illustrious Bessel for this country, had been as promptly improved! The Pulkowa observatory has lately obtained the unpublished manuscripts of Kepler, and we look forward with great earnestness to their publication.*

As we have already stated, the indirect advancement of science by the education and cultivation of students of astronomy, is one of the chief objects of the Central Observatory. To fulfil this object without interfering with the labors of the regular astronomers of the establishment, (each of whom has his own particular instrument, for which he is responsible, and with which no one else has any thing to do,) four small detached observatories have been erected for the smaller instruments, designed for the use of young astronomers, or for navy officers preparing themselves for geographical observations.

The observatory is crowned by three imposing cupolas, the central one of which contains the great refractor, and the eastern the heliometer. The western tower is intended to support a seven-inch Munich refractor, which has, however, not yet been ordered. In the meantime, it is provided with comet-seekers, which are placed at the disposal of any of the young astronomers or students of the St. Petersburg university who may desire to use them.

The only other room to which we will allude, is the small one immediately over the furnace, on the left of the grand

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* For a minute description of the rarest works in this library, see the Bulletin of the Petersburg Academy of Sciences, T. X. No. 4.

entrance, and directly opposite the flight of stairs leading to the central tower. This room can be heated to a very high temperature, and is used for testing the chronometers offered to the observatory.

The cellars, or rather passages beneath the edifice, which are usually kept walled up, were opened on the day preceding our departure, and the colossal foundations of the piers exposed to view. It is of the first importance, not only that all the instruments should be fixed on foundations as firm as possible, but that these foundations themselves should not be exposed to variations of temperature, especially in a climate like that of Russia. Little, indeed, as the English Astronomer Royal remarked on his return, "little do persons who merely look in a cursory way at the observatory suspect what masses of brick-work are concealed beneath their feet." The foundations descend below the depth to which the winter's frost reaches, and thrice as much mason-work is concealed below as is exhibited above the ground. Struve lays great stress upon the principle, that the bases of the fixed instruments ought to rise as little as possible above the level of the ground, on account of the unavoidable influence of changes of temperature. It is necessary merely to raise them to a sufficient height to free the visual ray even in the horizon from the refractions, and perhaps diffraction, which a too great proximity to the earth would produce. This height was fixed for the Pulkowa observatory at thirteen feet; and to protect the superterraneous parts of the bases as much as possible from the influence of changes of external temperature, or at least, to ensure that this influence shall be as slight and gradual as circumstances may admit, they are insulated from the external soil by double walls, and arched over with vaults pierced only in the places through which the piers rise. The double walls serve at the same time as foundations for the walls of the observing rooms.

Another principle established by Struve is, that the walls of the places of observation should be constructed as lightly as the nature of the case will allow; that is, of wood. "For a fixed instrument," he says, "the portion of the observing hall above the floor plays the part of a great box for the shelter of the instrument, provided with openings conveniently situated for making the observations. The cupolas which cover the equatorial instruments ought to be boxes of the same kind, but capable of revolving."

For all accurate observations it is indispensably necessary that the temperature of the air should be the same internally and externally. This is requisite, not only on account of the different directions which the visual ray would assume in air of different temperatures, thus rendering the observed place of a heavenly body inaccurate, — but also on account of the currents which would otherwise prevail at the apertures, and thus render the images tremulous and ill defined. For the same reason, then, that the foundations are carefully protected from the influence of the external air by the double brick walls, the walls of the rooms for observation, as well as the cupolas, are constructed of wood, and as slightly as is consistent with proper strength, in order that the interior may as nearly as possible preserve the temperature of the external air. The only purpose of these constructions is to preserve the instruments from the sun and wind, moisture and dust. A great disadvantage, too, of brick walls or metallic roofs to observing apartments is, that they condense the atmospheric moisture when the air suddenly becomes warmer, especially in spring, and thus expose the instruments to dampness, which is hardly to be considered desirable.

To the east and west of the observatory proper, which we have endeavored thus briefly to describe, are the dwelling houses. A description of them does not properly belong here. It was the aim of the architect to make the houses as comfortable as the climate and country would allow, and even during the rigors of a Russian winter, the temperature in the dwellings attached to the Pulkowa observatory is undoubtedly more mild and equable, than in the majority of Boston houses.

Attached to the observatory are various workshops, and already the mechanical department furnishes a large proportion of the smaller instruments used in the other Russian observatories. It has especially acquired a high reputation for its ether-levels, and those of Brauer, the Pulkowa mechanician, are equalled only by those of Repsold at Hamburg. Every Pulkowa instrument has levels from one or the other of these makers, and all the levels are protected from radiant heat by glass cases, — a valuable suggestion of Struve, which has already been adopted in Berlin and at Altona.

The 'Uranian colony of Pulkowa,' to use again one of Biot's phrases, consisted last summer of one hundred and eighteen persons, if our memory serves us right. In this number all the *employés* are included, as also the domestics,

who are veteran soldiers detailed for this service. The total cost of the observatory, excluding the value of the land and all salaries, was 2,100,000 rubles assign., or about $500,000.

Such is the Russian Central Observatory. Built under advantages such as never before existed, and most probably never will again exist in our day, it is the harmonious "expression of a scientific idea."

The chaste and elegant architecture of the building proclaims in every part and every form the Temple of Science. The director of its activity was among the directors of its construction, and his station in the empire, and position among the astronomers of our century, the world knows. The pecuniary resources were absolutely unlimited; and, as Airy justly observed, "while it is nobly and expensively constructed, it is not constructed extravagantly, or with a disregard of expense; while on the one hand it is worthy of an emperor, it is on the other hand built in a style which ought not to be displeasing to a minister of finance." The most skilful artists of the age exhausted their skill and ingenuity upon the instruments, so that to order the best refractor, the best meridian or vertical circle, the best transit instrument, the best clock, which can at this day be made, we say, "Let it be like that in Pulkowa." Whatever steps can be taken to make its library more complete, the director and his agents take. It remains but to speak of its activity. What has it done? What is it doing?

The chief energies of the observatory have, as we have already stated, been dedicated to the advancement of stellar astronomy, — as much regard being had to the observation of the bodies of our solar system as is compatible with the end proposed. The observations during the ten years of its existence have been chiefly as follows: —

With the Prime Vertical Instrument, for determining the coefficients of aberration and nutation, and the parallax of fixed stars:

With the Vertical circle, for the more accurate determination of the law of atmospheric refraction, (the observations serving at the same time for a fundamental catalogue of declinations,) of the position of the ecliptic, and of the parallax of fixed stars, this instrument having likewise been used for taking declinations of the sun, moon, and superior planets:

With the Transit Instrument for a fundamental catalogue

of right ascensions, and for those of the moon, and superior planets:

With the Meridian Circle, for refraction, for a catalogue of the declinations of fundamental circumpolar stars, and for declinations of sun, moon, and superior planets:

With the great Refractor, micrometric measurements have been made of double and multiple stars, and for the determination of parallaxes, — observations of the comets of short period, when lost to view at other observatories, — and observations of the satellites of Uranus and Neptune.

Beside these, subsidiary operations have been made in correspondence with the colossal survey of the Russian empire, which has been long carried on under the superintendence of the Director of the Observatory, and more recently, of his son, Mr. Otto Struve. The immensity of the region over which the survey is extended, stretching from Finland to Hindostan, and from the confines of Bohemia to the Chinese frontier, precludes the usual methods of measurement; and a large majority of the latitudes and longitudes have been determined solely by astronomical observations, and with a precision perfectly satisfactory to the Superintendent.

But the labors of the observatory, in connection with the measurement of the meridian arc in Finland, are of still greater importance. The measure of this arc was commenced under Struve's direction in 1830, for the purpose of connecting the great Russian arc with the one measured in Lapland, by the Swedish astronomers, at the commencement of this century. It was completed in 1846, and in fulfilment of a new order of the emperor, this colossal arc is now to be extended in a southerly direction as far as the Danube. The measurement is now nearly completed, and we shall soon have the length of an arc of the meridian extending over 21° 48′ of latitude, from Ismail, latitude 45° 20′ N. to Pahlavaara, latitude 67° 8′ N.

The number of young astronomers, who have already availed themselves of the advantages offered them by a residence at Pulkowa, is between fifteen and twenty, so that the four little detached observatories have been in almost constant activity since their first establishment; and Danes, Prussians, Austrians, Swiss, Fins, and Swedes, as well as Russians, have been through an apprenticeship there, and returned to disseminate in their respective countries the rich experiences thus acquired. And while the observatory has been of great service to these young men, they have rendered essential aid in the reduction of observations.

The Pulkowa Observatory has already given to the world entirely new determinations of the constants of precession, nutation, and aberration, in memoirs as remarkable for elegant analysis as for accuracy,—memoirs which have already become classic. Two important chronometric expeditions have been made; the one between Altona and Greenwich, the other between Pulkowa and Altona. Numerous smaller astronomical papers and geographical memoirs have been published. But the *Recherches sur la Parallaxe des Etoiles Fixes*, published by Dr. Peters, in October last, must rank among the most remarkable works of this century. We simply allude to it, without attempting even a description, as the importance of the subject and the work alike forbid superficial views.

Through the liberality of the Petersburg Academy, of which the Pulkowa Observatory forms a department, copies of the Description of the Observatory have been forwarded to all the observatories, and to some of the public libraries of the United States. Although the costliness consequent upon its magnificent execution, would probably put it out of the power of many private individuals to possess it, it is thus placed within the reach of all our astronomers. It must be their text-book.

Mr. Struve closes his description in the following words: — "Those who have read this description will cordially agree with the author, when he designates the foundation of the Central Observatory of Russia as an epoch in the history of astronomy; inasmuch as the history of science cannot furnish a single example of protection so liberal as that which has been accorded to it by the emperor Nicholas. The results of the labors of the commission and the exertions of the astronomers during the first years of the observatory's existence, will justify the thesis which I here propound, — 'that the observatory of Pulkowa is to be regarded as the realization of a scientific idea, clearly conceived, and executed with the illimitable means furnished by the munificence of its founder.'"